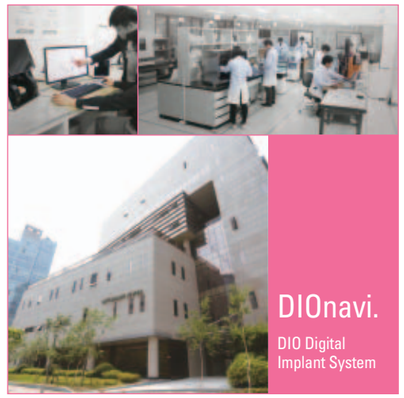


DIOnavi.

DIO Digital
Implant System

Digital Treatment No.1 DIO

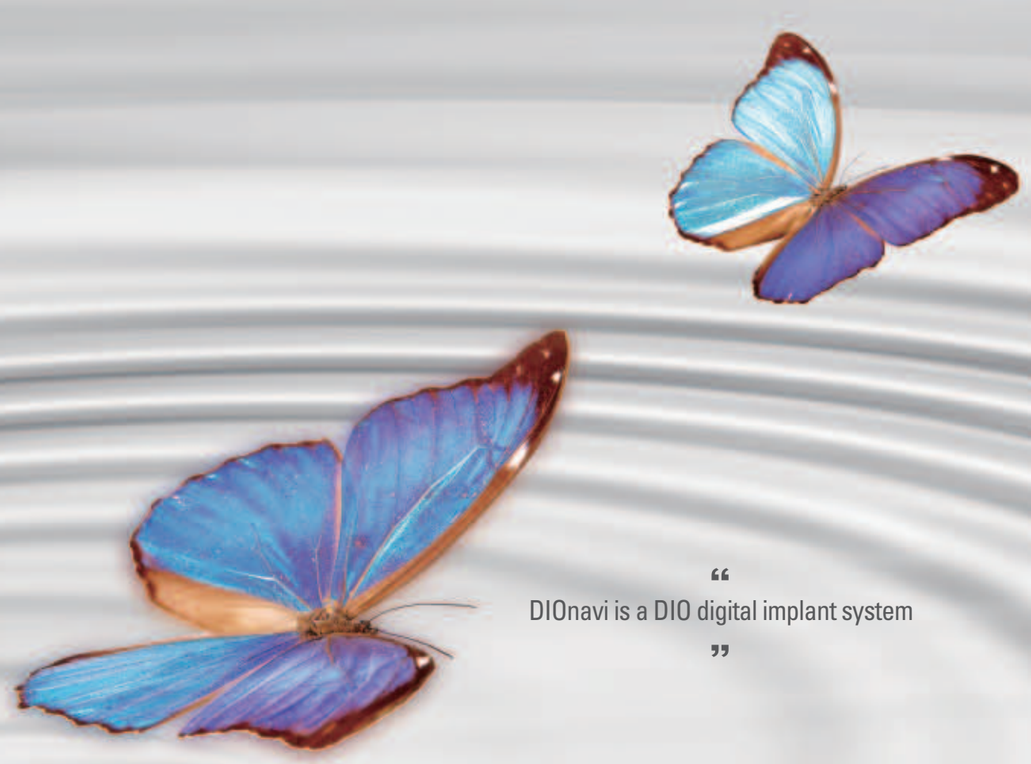
Deviation rate average of 0.9 degrees, greatest accuracy and stability

DIO navi.

DIO Digital Implant System

DIO IMPLANT CE 0123 GMP KOSDAQ

headquarter | 66 Centum Seoro, Haeundae-gu, Busan, 621-020, Korea T.+82 51 745 7777



“
DIOnavi is a DIO digital implant system
”

DIOnavi

DIOnavi brings a butterfly effect to patient marketing and dental treatment system.

1st Generation 2D Panorama Stent
Panorama image,
stent considering the approximate prosthetic relationship.
Only used as reference

2nd Generation CT Analog Guide
CT guide in the early 2000s
that applied a CT image

3rd Generation CT+Impression Analog Guide & RP Guide
Took the impression stone model with a CT.
Produce by introducing a coordinate concept on S/W

4th Generation CT + Oral scan Surgical Guide

DIOnavi.
Digital Impression.
Modeless Customized Abutment Design.
3D Printing & CAD/CAM

What is DIOnavi.

4th Digital Implant System

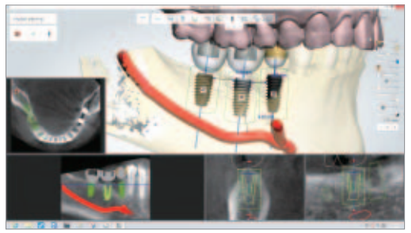
DIO navi is
an equipment that 100% digitalizes the whole treatment process
and it is optimized to complete the implant treatment without taking an impression.
Especially, DIO navi surgical kit will provide not only optimal convenience and
accuracy to the doctors but will also provide comfortability to the patients

Greatest accuracy and stability

Through implant planning that considered occlusion and stress dispersion,
DIOnavi Digital Implant System increases the accuracy of the implant treatment and
enabled 3D simulation that is used for patient counsel purposes.

- ☑ Digital Diagnosis
- ☑ Planned implant treatment
- ☑ Digital impression
- ☑ Customized prosthetic

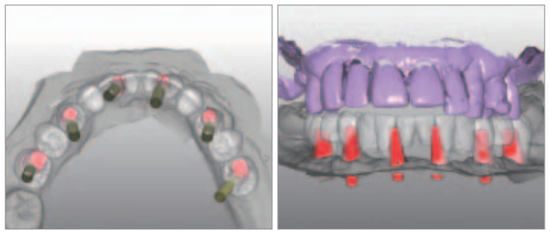
DIOnavi Treatment



Implant can withstand the highest load because the crown is designed first in consideration of occlusion and stress diversion, followed by fixture placement

VS

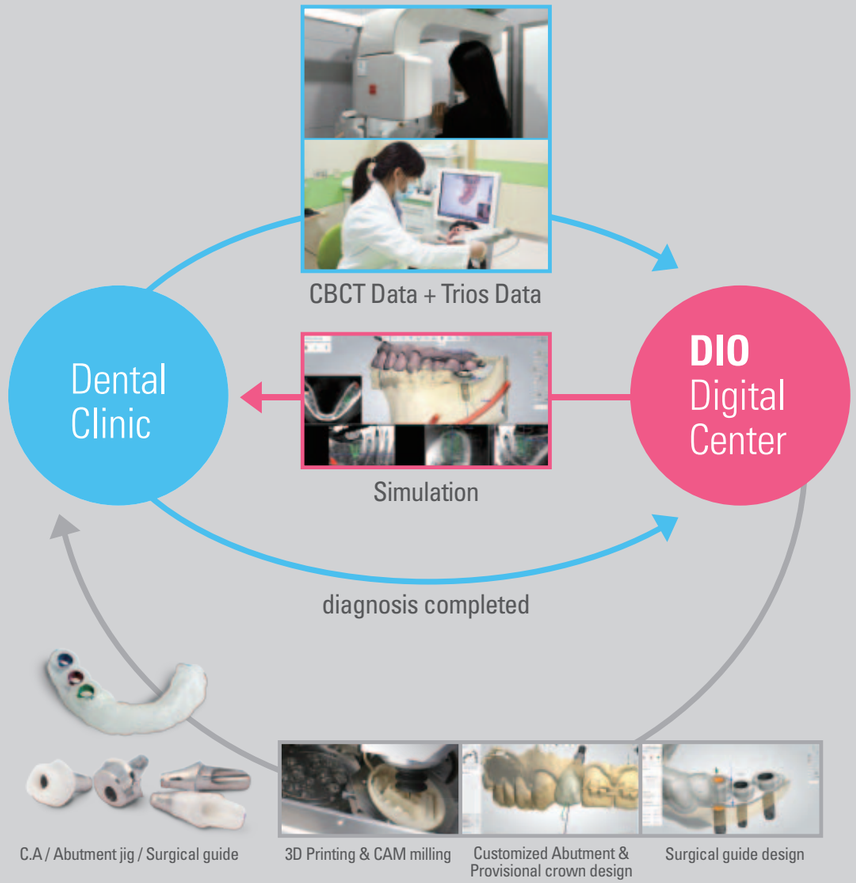
Normal Treatment



Due to the fact that it is difficult to adjust the center of the implant and crown, the load is not effectively dispersed and this may lead to prosthetic fracture of failure of implant placement.

DIOnavi. One-Step Protocol

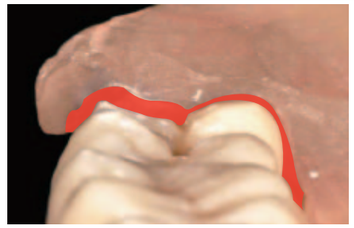
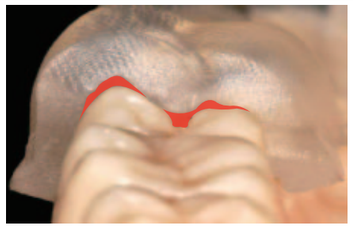
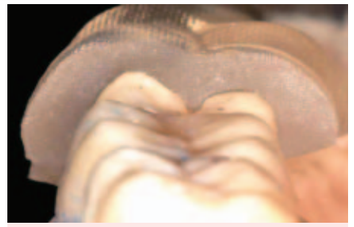
if CT data and oral scan data were sent to the DIO digital center,
implant treatment is possible with a surgical data created with a 3D printer in a week.



5 days of production period After confirmation

Realization of errorless treatment with an exact surgical guide

Surgical Guide | Analog vs Digital

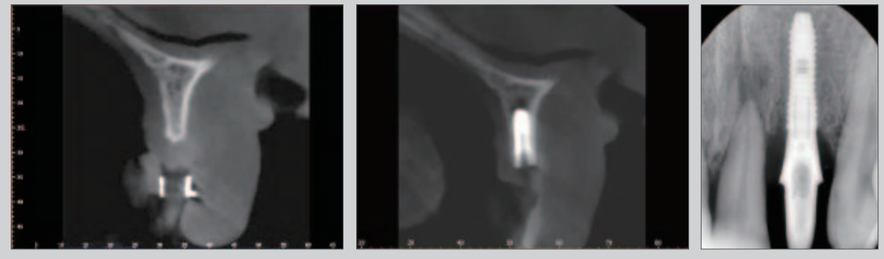
Analog	manufacture after plaster scanning	DIOnavi.
		
Guide produced in plaster model	Guide produced by scanning the plaster mode	**Guide produced by scanning the oral cavity**

Surgical Guide | Other Companies

	N Company	M Company	DIOnavi.
Impression	Alginate Impression Stone Model	Alginate Impression Stone Model	Digital Oral Scaning
Guide height	9mm	12~13.5mm	9mm
Recommended Drilling RPM	1,000~1,200 RPM Irrigation	1,000~1,200 RPM Irrigation	50 RPM No Irrigation
Degree of Precision before and after surgery	0.1~15.3 degree Average of 4.9°	0.1~5 degree Average of 2.5°	**0.1~1.9 degree** Average of 0.9°

Great precision and stability in existence

- Procedure deviation average of 0.9° (greatest exactitude with 1.9° at most)
- Exact oral data acquisition with CT and Digital Impression



Literature	Deviation
D'haese. Clin Implant Dent Relat Res 2009	2.6°
Van Assche N. Clin Periodontol 2010	2.7°
Ozan O. J Oral Maxillofac Surg 2009	4.1°
Sarment DP. Int J Oral Maxillofac Implants 2003	4.5°
Di Giacome GA. J Periodontol 2005	7.3°
Valente F. Int J Oral Maxillofac Implants 2009	7.9°
Ruppin J. Clin Oral Implants Res 2008	7.9°
DIOnavi.	0.9°

※Reference : Thesis about Guide system comparing the degree of precision

Doctors & patients' convenience provides a Butterfly effect

Because DIOnavi is a flapless surgery, the pain and swelling decreases,
and it is suitable for patients with diabetes, high blood pressure, mental disease
and it can create a new blue ocean such as
busy businessmen, patients who were afraid to get a surgery, and senior implant.
All of DIOnavi procedure takes only 10~20 minutes (1~2 unit)

Time for DIOnavi system to make a temporary prosthetic – average of 5~7 days

Time for normal implant to make a temporary prosthetic – average of 4 months

The DIOnavi system is fast and accurate because the total process is digitalized.

☑ **Less pain**
There is less pain due to no incision

☑ **Less bleeding**
There is less bleeding due to no incision

☑ **No suture**
There is no suture due to no incision

☑ **No damage**
There is no damage of surrounding nerve or teeth due to the use of exact guide

☑ **No inconvenience**
Can be treated without inconvenience due to the use of comfortable guide

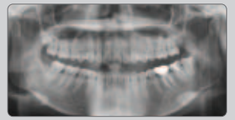
Normal procedure vs. DIOnavi procedure

☑ Average time that takes for normal treatment (1~2unit)

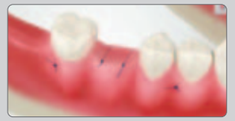
Surgery 50 minutes + maxillary and mandible impression taking 20 minutes / stone model creation 40 minutes + 20 minutes
= 130 minutes (To temporary prosthetics)

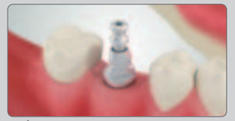
☑ Average time for DIOnavi (1~2unit)

Surgery & temporary prosthetic 15 minutes
= 15 minutes (To temporary prosthetics)

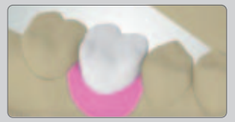

Counsel and CT scan


1st surgery & Suture


Stich out


2nd surgery


Impression taking

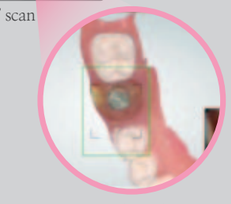

Temporary prosthetic


Final prosthetic

About 123days till temporary prosthetic (minimum of 4 months)

Average of about 5 ~ 7das till temporary prosthetic


Counsel and CT scan


Digital oral scan

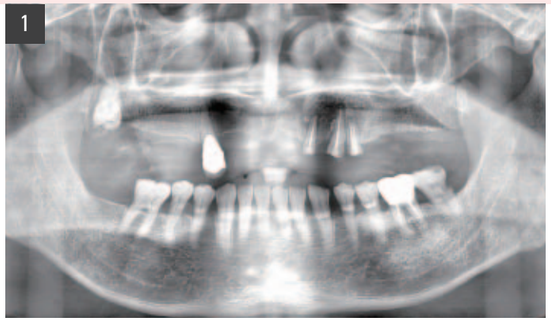

Surgery and temporary prosthetic installation


Final prosthetic

Implant treatment 3D diagnosis and simulated surgery system

Not only the mock implant surgery plan that considered the occlusion and stress dispersion,
but 3D simulation that can be used as a counseling material for the patient is provided.
The doctor can establish a satisfactory treatment plan and with a provided surgical guide,
He can operate a safe and accurate procedure.

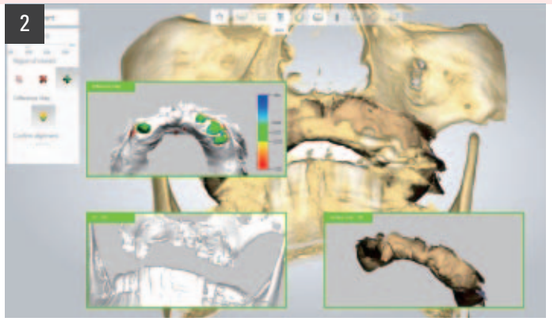
1



History Taking

The patient has a history of general disorder such as high blood pressure and diabetes, slight paralysis due to stroke,
and uses full dentures with only one canine tooth which is wobbly.

2



Scan Aligment

Align the CT data and trios oral scan image

3

Virtual Crown set up

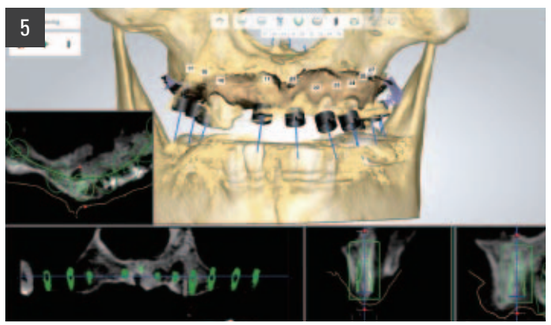
Place the virtual crown for the optimum implant position

4

Simulation

Modify the tooth placement and design and obtain the best occlusal status.

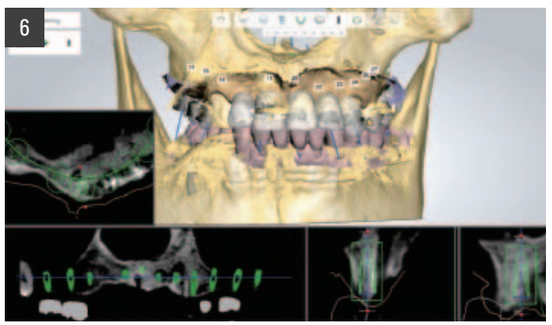
5



Implant Planing

Consider the crown location, design, occlusion, bone density and nerve location to set the optimal implant location

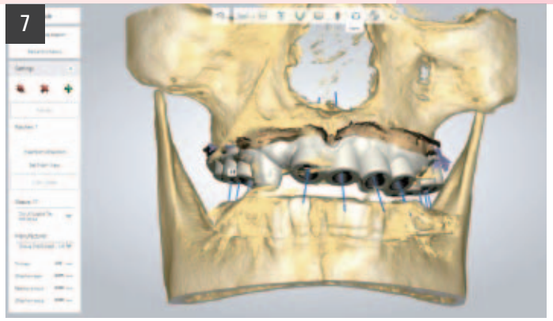
6



Implant Simulation

Check the implant occlusion and path that considered a prosthetic relationship in a top down method

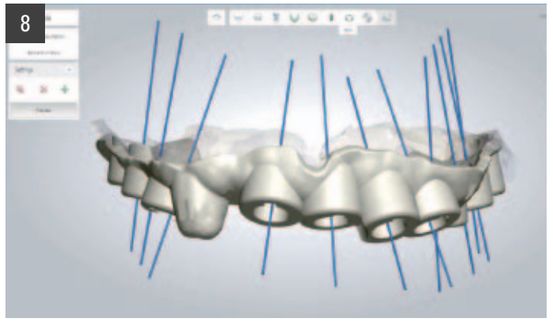
7



Surgical Guide design

Surgical guide is automatically designed adjusted to the planned implant placement location,
and exact placement direction and location can be confirmed.

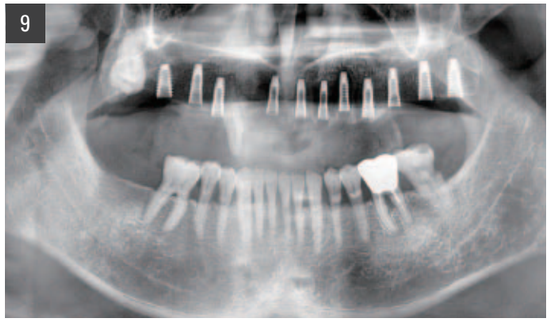
8



Finish Design

The optimal surgical guide design that considered patients' bone density, prosthetic location and occlusion relationship is completed

9



Implant Surgery

Procedure case that used DIOnavi surgical guide

10

This is a CT image of the implant that is placed exactly on the spot it was planned

DIOnavi.

DIOnavi. Surgical Kit_ *Drills Swiss made*

The first step to the perfect implant placement

When performing a surgery with a surgical guide,
DIOnavi surgical kit is optimized to easily and accurately place implants
with the superb cutting force of swiss-made technology.

No water
- There is no water ponding during the procedure
- Provides comfort to patients

No suction
- Easy to collect autoskeleton

DIOnavi. Surgical KIT

No noise
- minimize noise with low speed drilling and no suction

No heat
- low speed drilling below 50rpm
- use a Swiss drill with great cutting force

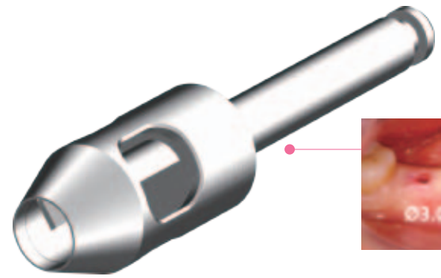
DIOnavi. Master Kit

Kit that can place UF(II) Narrow and Regular Fixture

DIOnavi. Starter Kit

Simple kit that can place the fixture
with length 10mm, 11.5mm
and diameter 3.8, 4.0, 4.5 that is used most

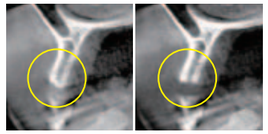
DIOnavi. Surgical Drill Components



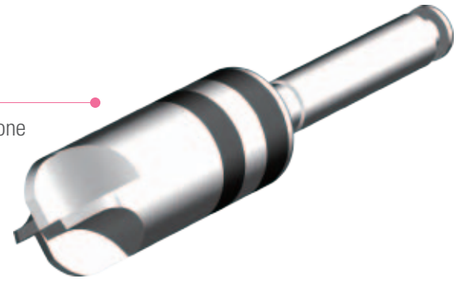
Tissue Punch

Removes the soft tissue on the alveolar gum where the implant will be placed.
It has a second blade inside that cuts the gum and removes it at the same time.

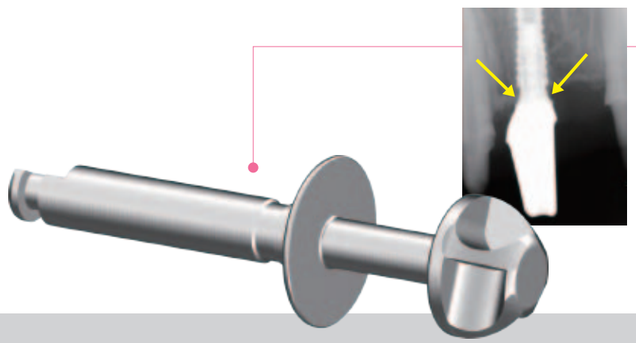
Bone Flattening Drill



Bone Flattening Drill flattens the bone surface for an accurate 1st drilling



Abutment Profile Drill



Abutment Profile Drill removes the bone and gum that bothers the abutment placement.
Able to adjust the height with a stopper and form an abutment profile by spinning 360 degrees.

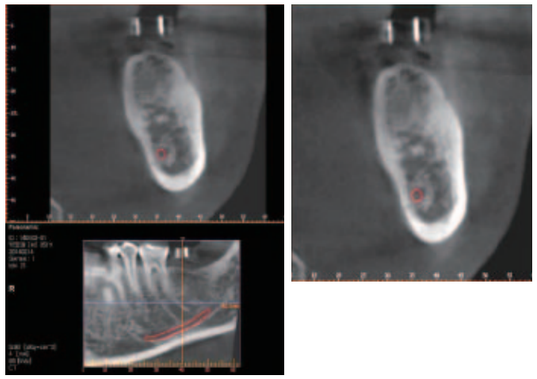
DIOnavi.

DIOnavi. Clinical Case_ **01**

- Name : PPG (52/M)
- Date Of Surgery : 2014. 02. 14. (Segyero Dental Hospital)
- Surgery Done By Dr. Chung Dongkeun
- Pre-Medical History : N/S
- C.C : I want to place implants where there are no teeth

[**Patient Information**]
Patient who is sensitive to small stimulation, easily gets cold sore in the mouth, and has severe stomatitis.

Pre-operative CT



CT image cutting

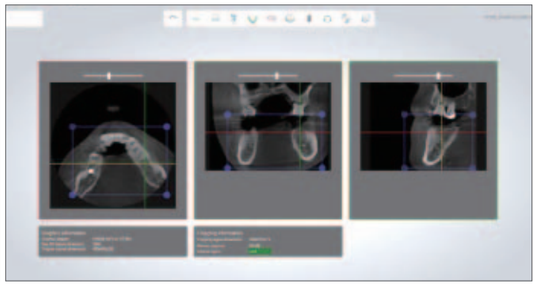
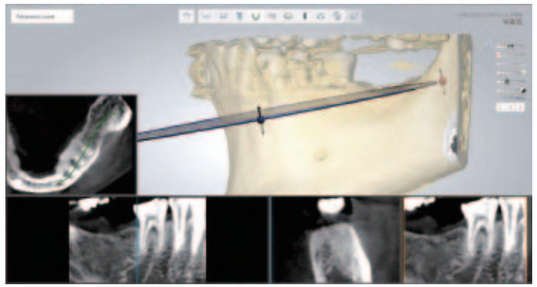


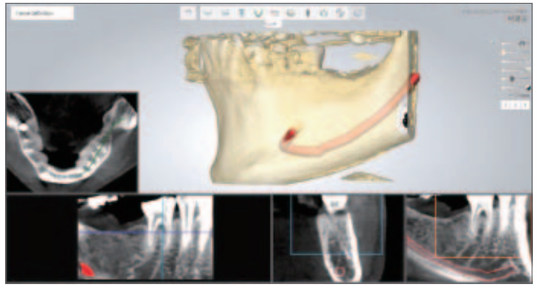
Image matching

Match the Trios scan file and CT image file, the rate of matching is higher with greener colors Set up plan

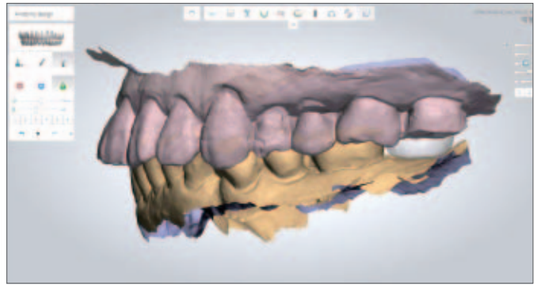
Set up plan



Detect a nerve

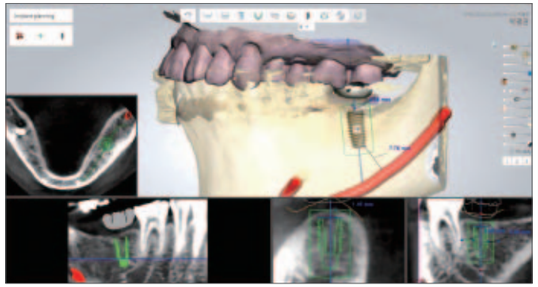


Virtual

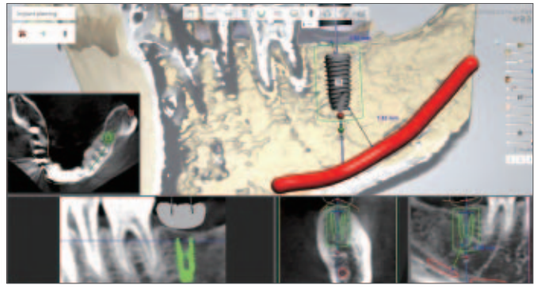


Design a virtual crown

Implant Planning -1

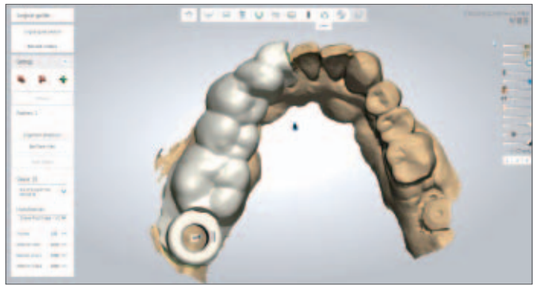


Implant Planning -2



Design a fixture size considering the location of the inferior alveolar bone nerve, relationship with the adjacent teeth, and quality and quantity of bone

Guide Design



Set the range of surgical guide for a sufficient stability and retention.

Surgical guide materials

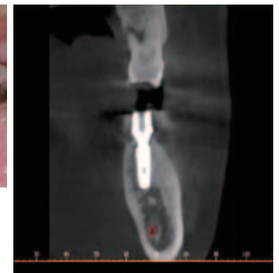
Surgical guide Customized abutment & PMMA Provisional crown (14.02.14)

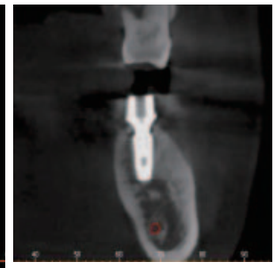
Intra-operative Photo

Teeth surrounding the surgical area secure the stability of the surgical guide
Drilling is easy because the guide is manufactured lower than the occlusion level,

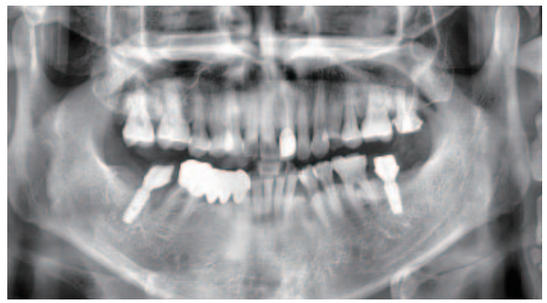
Autogenous bone that is collected with no irrigation and low RPM

Locate the screw hole in the center





You can see that the relationship with the antagonist tooth is good



#47 is a fixture that is planted in a common way and the fixture and abutment is tilted toward the abutment mesial.

#37 is a fixture that is planted using a surgical guide, and the abutment is located in the center.

When compared the two methods, if one proceeds with the surgical guide op that considered the prosthetics' function, the abutment shape will be fabricated in an ideal way.

Abutment + Provisional crown connected on the day of the surgery
Flapless surgical method is favorable functionally and esthetically, and the complications are minimized after the surgery

DIO navi.

Korea Dental News published document

Professor Choi Byung Ho

1982 ~ 1985 Training at the Oral & Maxillofacial Surgery Dept., Yonsei University, Korea
1989 ~ 1991 Training and Ph Degree at the Oral and Maxillofacial Surgery Dept., Freiburg University, Germany
1992~present Professor, College of Dentistry and Wonju College of Medicine, Yonsei University
Awards Best Paper Award for 2008 by the journal "Oral Surg Oral Med Oral Pathol" in USA

Book publications
- Flapless Implantology. Quintessence Publishing Company, 2010.
- Flapless Implantology in French ed. Quintessence Publishing Company, 2012.

Contents

- From Initial Diagnosis to the Final Prosthesis: Full Digitalization (First)
- From Initial Diagnosis to the Final Prosthesis: Full Digitalization (Second)
- Computer-Guided Flapless Implant Surgery (First)
- Computer-Guided Flapless Implant Surgery (bottom)

Professor Choi Byung Ho

Dental News published document

From Initial Diagnosis to the Final Prosthesis: Full Digitalization (First) Outline

There are two types of dental implant treatment systems: analogue and digital. Analogue system involves the act of manually creating the prosthesis using plaster casts, while digital system, uses CAD/CAM scanned image instead. Digital system has had limited uses thus far in the overall implant treatment procedures.

Digital system was utilized in designing the surgical guide and abutment after the plaster cast had already been manually created (1). Or the digital system was used to model the upper prosthesis using the scanned image of the placed implant area (2)(3). However, the efforts to digitize the entire process, from initial diagnosis, designing surgical guides and developing both temporary and permanent prosthesis, had not yet been fully realized. This paper therefore, attempts to suggest a method where the whole implant treatment procedure can be 100% digitized, eliminating the need for impression-taking and cast-making.

Analogue System vs. Digital System

There are a number of steps involved in an analogue system. Firstly, impression material is used on the desired area to obtain a basic outline, which is then filled with plaster material to develop a cast. After removing the wax from the cast, either gold or ceramic can mold the shape. This cast is also used to design and develop the surgical guide. As noted, impression taking constitutes the beginning of the analogue system. Thus, if a bad impression is developed, rest of the steps becomes difficult and the final prosthesis will lack precision. Therefore, the impression-taking process is a difficult and time-consuming process for the practitioner. In particular, extra time and attention is needed to accurately capture the cervical margin of the implant abutment during impression-taking.

Moreover, the patient must oftentimes endure the discomfort of waiting for impression material to solidify inside the mouth and those patients with a weak stomach may suffer from nauseous feelings

Image 1: Impression taking

Making the plaster cast is not only untidy but the cast itself may be damaged during the process. The impression material itself poses significant limitation due to its tendency to expand or contract. Another disadvantage comes from the fact that the cast must be mailed to the laboratory for production, thus, delaying the entire process.

These disadvantages of the analogue system do not occur in the digital system. Rather than using impression materials to obtain the shape, in a digital system, oral scanner is used to simply scan the necessary area and then a 3D printing or a milling machine is used to produce a physical model of the scanned image. In addition, since the image is immediately manufactured into a physical model, the abutment tends to be highly precise. Moreover, since the cervical margin is matched with the gum's shape directly in the scanned image, a more detailed and accurate prosthesis can be developed. The data is also simply sent over the Internet, significantly reducing time it takes to manufacture the prosthesis. Other advantages of using the digital system include being able to accurately diagnose implant's position using the scanned image, which then allows accurate designing of the surgical guide. Practitioner can also take advantage of the digital system by developing customized abutment and crown pre-procedure for more aesthetically pleasing results but also surgically advanced implant to mitigate potential defective results. Digital system can reduce both the number of patient visits for procedure and practitioner's time spent on the procedure as well as provides higher quality prosthesis for the patient.

Digital Implant System Steps

1. Digital impression

Digital implant system begins with digital impression. Digital impression refers to the scanned image, which was obtained using an intra-oral scanner inside the mouth. Intra-oral scanner TRIOS™,

Image 2: TRIOS™

developed by Denmark's 3shape, can take over three thousand 2D images per second to create a highly accurate 3D digital model.

Image 3: Oral scanned image

2. Digital Implant Treatment Plan

The patient's oral scanned image and Cone Beam Computed Tomography (CBCT) of the jaw is compiled together using diagnostic software. This complied image illustrates the anatomical structure of the teeth, gum and jaw in one Image, and also allows the implant's placement position to be analyzed and designed more effectively .

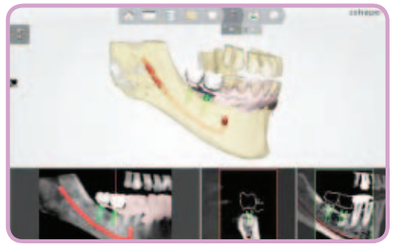


Image 4: Image of implant diagnosis

There is a number of diagnostic software available in the market and the most well known software is a 3D modeling software called Implant Studio ™, developed by 3Shape. Implant Studio™ matches the digital image from the oral scanner and the image from CBCT to help make a decision regarding the implant's placement position.

3. Developing Digital surgical guide

Once the placement position has been determined, surgical guide can be designed using the oral scanned image.

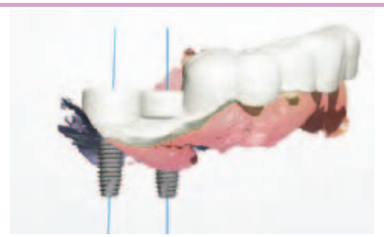


Image 5: Designing the surgical guide

Implant Studio ™ can diagnose the implant position but also design the surgical guide. There are mainly two methods of developing a tangible model from the 3D digital image, either with a 3D printer or a milling machine. 3D printer basically functions by first reading the design from a 3D printable file then shooting UV laser to lay down successive layers of material and building the complete 3D model from a series of cross sections.

Image 6: Image of the surgical guide developed using 3D printer

There are a number companies who produce 3D printers. Of these, the US-made ProJet 3510 MP model by 3D Systems is small in size but also precise.

Image 7: ProJet 3510 MP, a 3D Printer

4.Digital production of a customized temporary prosthesis The implant placement position (determined by using Implant Studio™) is loaded onto the 3D modeling software called Dental System™, which is also developed by 3Shape.

Image 8: Image illustrating implant and the structure of the neighboring area

This software is used to design the abutment and crown by analyzing the relation of the following elements: implant's proposed placement position, neighboring gum shape, adjacent teeth, and antagonist teeth.

Image 9: Designed implant and abutment

When developing the abutment and the implant, a milling machine is used. One of the technically advanced milling machines in the market is the Arum 5-Axis Milling Machine, developed by Doowon.

Image 10: Arum 5-Axis Milling Machine

In addition to the three axes, X, Y and Z, this machine further added B and C axes for more accurate designing of even the more complex images in just one sitting.

Various material can be used to manufacture the appropriate abutment or tooth including zirconia, glass ceramic, titanium and PMMA. In a procedure involving a surgical guide, a slight deviation can occur while inserting the implant than it had been initially planned. To combat this issue, a more easily adjustable upper abutment is made using PMMA to be placed over the implant immediately after placement.

Image 11: Abutment (A) and Tooth (B) milled using PMMA

This upper abutment can be manufactured pre-surgery, which then allows for immediate upper prosthetic restoration upon placing the implant.

5. Implant surgery

Using a surgical guide makes flapless procedure a possibility. This is because the surgical guide contains all the necessary information, including implant placement position, direction of placement, and drilling depth. The position, direction and drilling depth is guided by the surgical guide and therefore, the implant can be placed more accurately without having to open up the gum to locate the bone.

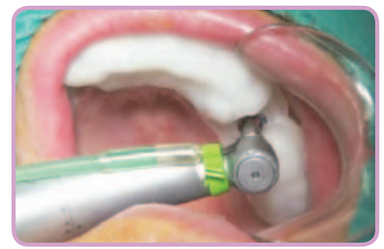


Image 12: Undergoing procedure with surgical guide

The advantage of the flapless surgery is that any aesthetic prosthetic restoration can take place immediately after the implant placement. This is due to the fact that soft tissue profile of the alveolar region is stabilized even post-surgery (4)(5).

Image 13: Soft tissue profile comparison with immediate prosthetic restoration under flapless method. You can see the stability 4 months after the procedure

It is important to select the right equipment when using a surgical guide. The precision levels of the surgical equipment can lead to potential errors during drilling and placing implant(s). Moreover, equipment choices can alter the comfort level of both practitioner and patient during the procedure.

Therefore, both the levels of precision and comfort should be taken into consideration when selecting the surgical instrument. The instrument must also be compatible with the surgical guide, so a particular company's implant products are going to be used for the procedure, then surgical instrument and surgical guide must also be from the same company. There are also software that accurately illustrates the bone density level (in Hounsfield Unit) of the implant placement site according to the implant's height and width.

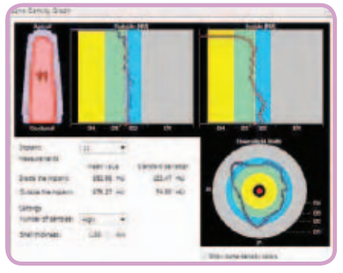


Image 14: Accurately illustrating the bone density level of the proposed implant placement area according to implant's height and width in Hounsfield Unit.

So this kind of software can be used to calculate the bone density level before the surgery and allow drilling sequence to be planned accordingly, which can help achieve initial fixation.

From Initial Diagnosis to the Final Prosthesis: Full Digitalization (Second)

6. Implant Digital Impression

Immediately after placing the implant, place the scan body on the implant to scan for digital impression .

Image 16: Image of scan body placed on the implant

Image 17: Image of digital impression of the scan body.

This digital impression is used to make the final prosthesis. Scan body provides necessary information for developing the abutment and crown later on (6)(7).

7. Immediate Restoration

Once the implant has been fixed on its initial position, place the pre-manufactured, customized temporary PMMA abutment and crown on the implant for immediate prosthetic restoration. If necessary, adjust the abutment and the crown inside the mouth.

8. Digitally manufacturing customized prosthesis

Use Dental System™ software to design the abutment and crown, using the digital impression obtained from the scanned image from step 6.

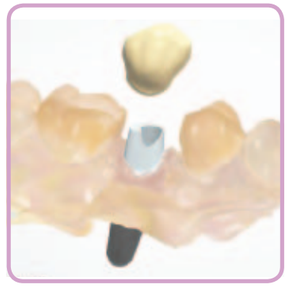


Image 18: Designing customized abutment and crown

Then, use the Arum 5-Axis Milling Machine to manufacture those abutment and crown. Titanium or Zirconia is used to make the abutment and zirconia is used for the crown.

9. Final Prosthetic Restoration

Depending on the level of stability with the implant bone marrow, final prosthetic restoration can take place 1-3 months after the surgery. This final stage involves connecting the customized abutment to the fixture and capped off with the crown.

CASE STUDY

A 39-year-old woman needed an implant on the maxillary right central incisor.

Image 19: Image of the patient's mouth

It was 3 months after from when the damaged tooth was removed and the surgery area had healed well. At the time, she was wearing a temporary prosthesis and she wanted a fast but also aesthetically pleasing permanent restoration. Radiographic analysis of the alveolar region showed a good bone height in the mesiodistal axis but only 5mm of width in the buccolingual axis.

Image 20: CT image of implant from buccolingual axis

The narrow width means the bone is susceptible to significant damage from the shaking motion of the drill. However, it was also not a good idea to try and expand the width of the bone through Guided Bone Regeneration (GBR). A better choice was to place the implant safely within the bone's narrow width. Therefore, it was decided to continue the procedure as originally planned. Using the initial implant position, as determined by the CT scan, a highly accurate surgical guide will guide the procedure. In addition, the flapless method was chosen to minimize bone loss from the surgery and slow drilling technique would be utilized to minimize the drill's shaking motion. Finally, prosthetic restoration would take place immediately after the implant had been placed.

Two elements were planned in the clinic. Firstly, maxillary and mandibular teeth were scanned using TRIOS™ and secondly, a CBCT was obtained pre-procedure. Following steps were taken to prepare for the surgery. The scanned oral image

Image 21: Scanned oral image

and CBCT image were superposed using Implant Studio™ software.

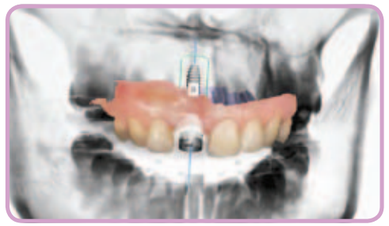


Image 22: Superposed image of scanned image and CBCT image

Image 23: Illustrating accuracy level of the superposed image. Green area means error range of 0.25mm

After determining the implant placement location, the surgical guide and customized abutment and upper tooth

Image 24: Designed surgical guide

Image 25: Customized abutment (A) and upper crown (B)

were designed. Surgical guide was made using a 3D printer, while the abutment and crown were made with zirconia via Arum milling machine.

Image 26: Final Abutment (A) and upper crown (B) made from zirconia, using the milling machine

Thus, the surgical guide, customized abutment and crown were all prepared before the procedure. BMD of the implant site indicated a D2 bone density level

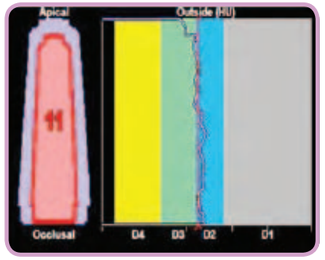


Image 27: Bone Marrow Density (BMD) of the implant site

and drilling sequence was predetermined like Image 28.

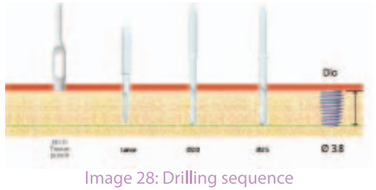


Image 28: Drilling sequence

After applying local anesthesia, the surgical guide was placed on the tooth. The procedure took place under flapless method using the surgical kit developed by DIO Implant. A 2.5 mm-diameter drill was used in accordance with the drilling sequence. Once the implant had been placed, the implant's insertion torque measured 35Ncm. DIO Implant's 3.8 mm x 13 mm UF Implant Fixture was used for the procedure. The total procedure took around five minutes. Stability level, immediately following the procedure, measured -2 on the perio-test. Once the initial implant had been stabilized, customized abutment and crown (made using zirconia) was placed and fixed on the implant.

Image 29: After inserting abutment

Image 30: After fixing the crown on the abutment.

The post-operation radiographs confirmed that implant had been placed with some room from neighboring teeth and its roots.

Image 31: Post-operation radiograph

CT image was taken to measure the success of the procedure – which confirmed that the implant was safely placed with just 1.1 degree of error within the bone.

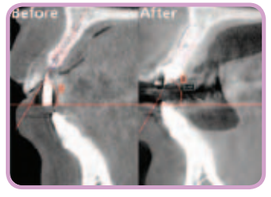


Image 32: Comparison of CT image, pre- and post- surgery

Conclusion

1. The entire procedure, from initial diagnosis to the final prosthesis, was done using digital system, without impression taking. It took just two visits to the medical facility to successfully restore the defected maxillary right central incisor using implant.

2. If the width of the alveolar is significantly narrow, just enough for the implant, the flapless procedure method and highly precise surgical kit can be utilized to safely place the implant.

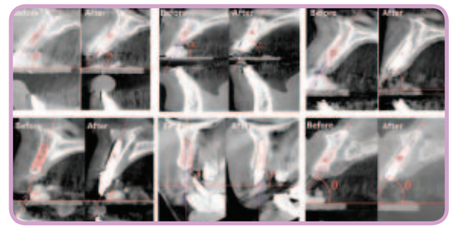


Image 33: CT images of the patients from digital implant system. Compares the planned and actual implant placement positions. Illustrates the accurately placed implants when using highly precise surgical guide, surgical kit under flapless method.

3. Proper use of flapless procedure with right surgical guide and kit can reduce need for undertaking GBR.

Computer-Guided Flapless Implant Surgery (First)

Abstract

In a computer-guided flapless implant surgery, all of the necessary information is determined pre-surgery. The Cone Beam Computed Tomography (CBCT) and computer planning software are used to capture the shape of the mouth, including alveolar, membrane and teeth in a 3D image. This image is used to determine the position, direction and height of the implant and this information helps design the surgical guide.

Image 1: Making a decision on implant's position using 3D digital image

This surgical guide is used to adjust the drilling position, depth and direction as necessary with a goal of accurately placing the implant.

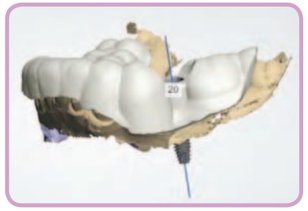


Image 2: Designing the surgical guide on the 3D digital image

In a flapless procedure, the implant can be placed, according to plan, without having to expose alveolar bone. In this procedure, selecting the surgical equipment is also very important. Two factors must be considered when making this decision: precision and convenience. Precision refers to the level of precision of both the drill and the implant placed. Convenience refers to the level of convenience for both the user of the equipment (practitioner) and the recipient (patient). Both precision and convenience must be taken into account when selecting the surgical equipment. Moreover, since the surgical equipment/ kit must be compatible with the surgical guide, the practitioner must make sure that the surgical guide and kit is developed from the same company as the one that developed the implant.

Surgical Equipment

Surgery guide-led, flapless implant procedure requires the following equipment: Soft Tissue Punch drill, Bone flattening drill, Guide drill, Final drill, drill tube, implant connector, and abutment profile drill.

Soft Tissue Punch Drill

A Soft tissue punch drill is used to drill a cylindrical shape into the gum in the flapless implant procedure.

Image 3: Opening a cylindrical hole for the flapless procedure

The recommended drill size is 3 mm in diameter.

Image 4: Soft Tissue Punch drill with 3mm diameter blade

Using a drill with a smaller blade diameter has two advantages. Firstly, smaller-sized opening means the membrane tissue around the implant is closer to the surface of the abutment, which has a hemostatic effect. Secondly, the wound tends to heal faster and leaves fewer scars. Soft tissue punch drill is shaped like a cylinder to match the surgical guide's guiding sleeve (so that the drill can be inserted into the sleeve and move according to the surgical guide). The blade has a circular shape, 3mm in diameter. Using a drill with a secondary blade within the circular 3mm blade can remove the incised gum parts as the gum is cut in a circular shape,

Image 5: Closer up of the Soft Tissue Punch Drill. This is a drill with a secondary blade inside the cylindrical body.

Soft tissue punch drill continues to remove the soft tissue until it hits the surface of the bone underneath, thus does not need a separate stop feature.

Bone flattening drill

If the surface of the alveolar crest is either pointed, slated or irregular, the drill can slip when it hits the bone, even with the use of the surgical guide.

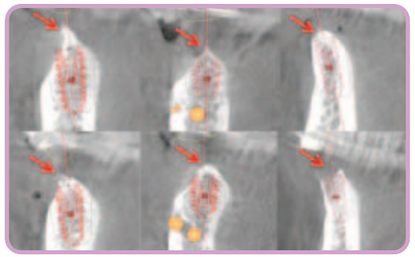


Image 6: Pointed or Irregular Alveolar crest

This can lead to displacement during drilling and also during implant placement.

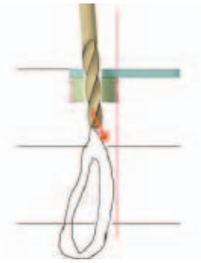


Image 7: Image of the drill slipping on the bone's surface

So there is a need for an additional step to smooth the surface and to prevent the slipping of the drill or implant. In the flap method, bone mucosa flap is exposed to flatten the alveolar surface.

Image 8: Flattening the bone's surface with a flap procedure

However, in a flapless procedure, bone flattening drill is able to flatten the surface of the alveolar crest without exposing the membrane flap.

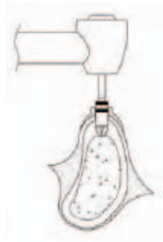


Image 9: Flattening the bone's surface with a flapless procedure

The drill also is shaped like a cylinder to fit the surgical guiding sleeve. In addition, there is a scale on the drill so the practitioner can identify the depth during drilling.

Image 10: Bone flattening drill

The drill has a horizontal cutting blade to be able to flatten the surface of the alveolar crest.

Image 11: Result of using bone flattening drill

Guide drill

Guide drill is used to make the first hole on the bone's surface. This drill has a spear-like sharp blade and a cylindrical body to match the drill tube.

Image 12: Guide drill

The Surgical guide helps guide the drill during the procedure. Guide drill's purpose is to create the initial precise location and direction for the subsequent drills to follow. It also has a stop feature on the body to prevent drilling beyond a certain depth. To use the Guide drill, firstly, matching drill tube is inserted into the surgical guide's guiding sleeve, then Guide drill is inserted into the tube.

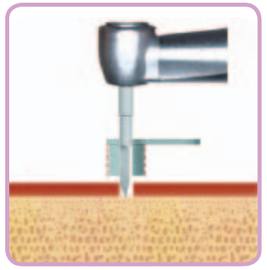


Image 13: Guide drill during procedure

Guide drill tends to be more effective and precise in establishing the initial path than the 2mm twist drill. However, it is ineffective to make an actual socket for the implant placement. A final drill is much more effective for that.

Final drill

This drill drills a hole in the bone necessary for placing the fixture. Drill is organized by height and diameter .

Image 14: Illustrating various lengths of the surgical drills

Image 15: Illustrating various diameter of the surgical drills

This drill also has a cylindrical body and a sharp blade. There is also a stop scale on the body to adjust the drilling depth. Drill's stop occurs between the top of the implant to the top of the surgical guide, in other words, height of the surgical guide and length of the implant put together constitute where the stop scale should be on the drill. Height of the surgical guide can differ depending on the company and there are a variety of options from 9mm, 10mm, 11mm, 13mm and 15mm. For example, if the surgical guide is 10mm in height and implant is also 10mm in length, then a 20mm stop scale is placed on the drill and it will stop when it digs a 10mm hole in the bone.

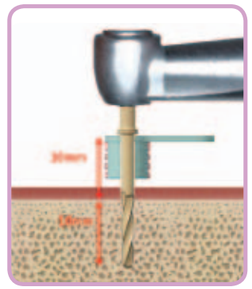


Image 16: Illustrating drilling depth for placing a 10mm implant

Drill Tube

Drill tube is inserted into the guiding sleeve to guide the drill's direction during the procedure.

Image 17: Drill Tube

The tube is made with titanium and has a stop function (height: 1mm) at the top. The tube's diameter matches the drill being used. The drill tube also comes with a handle to help insert it into the guiding sleeve. The shape and height of the drill tube differs according to the manufacturing company.

Image 18: Spoon-shaped Drill Tube

While offering convenience when holding, a spoon-shaped drill tube can actually alter the drill tube's angle during drilling and if it is used for rearmost teeth region, the patient's cheek can disturb the procedure. Alternatively, the drill tube with a short handle has two advantages. Firstly, the handle can be positioned either on the lingual or buccal side. Secondly, once the tube has been inserted into the guiding sleeve, it is unnecessary to continue holding onto the handle during the procedure.

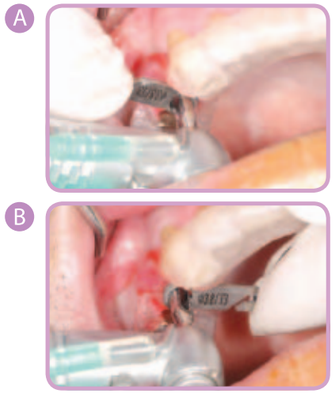


Image 19: Using short-handle drill tube. A: Positioning the handle on the buccal side, B: Positioning the handle on the tonsil side

However, its disadvantage is that with the short-handle drill tube, there is a chance that the tube can be dropped into the patient's mouth during the procedure. Therefore, it is a good practice to tie a string on the handle.

Image 20: String-tied drill tube

Attaching a string can also help when inserting and removing the tube from the guiding sleeve. Drill tube's height also depends on the manufacturing company. While using a drill tube with more height is one way to increase drilling accuracy,

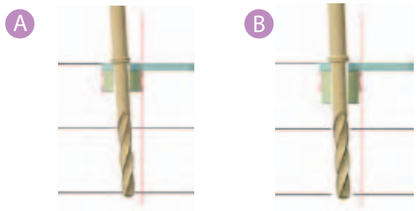


Image 21: Accuracy increase as length of the drill tube increases A: Short drill tube B: Long drill tube

it also means having to use a taller surgical guide, which can make the procedure more difficult. Therefore, it is a good strategy to use a shorter surgical guide with a taller drill tube. The drill tube that best accommodates this conundrum is the one that has a shape that is extended towards the bottom of the gum.

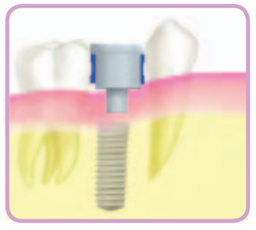


Image 22: Drill tube with extended length into the bottom of the gum

Implant Connector

Implant connector is used pick up and place the implant following the surgical guide.

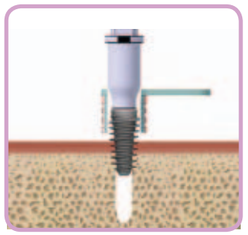


Image 23: Placing the implant with implant connector

It features a scale to identify the depth of the implant. For example, if the surgical guide is 9mm in height, implant connector has a scale 9mm above the implant. In addition, implant connector has a hexagonal marker.

Image 24: Illustrating location of the hexagonal marker on the implant connector and guiding sleeve

Through the act of matching the markers on the surgical guide and the one on the implant connector, the hexagonal marker helps to match the direction of the placed implant to the one that was planned during the diagnosis stage. The diameter of the implant connector is usually smaller than the diameter of guiding sleeve and it depends on the manufacturing company.

Image 25: Matching the markers on the surgical guide and implant connector

Image 26: Illustrating the difference between the diameters of the implant connector and guiding sleeve

Precision level increases as the difference in diameter becomes smaller (i.e. diameter of the two equipment are closer). But the smaller difference can also cause the equipment to jam together (3). Once they have been jammed together, the implant connector becomes difficult to separate from surgical guide. Therefore, connector must be designed to be precise but also possess ability to combat the potential jammed issue. One method is to minimize the surface area where the connector touches the surgical guide .

Image 27: Implant connector designed to limit the surface area facing the surgical guide to avoid jamming effect.

Simply add more space on the side not facing the surgical guide and design the connector so that if it cannot be removed by hand, it can be removed using another equipment. For example, design the implant connector it so that a crown remover can be used to remove it from the surgical guide.

Image 28: Removing the implant connector using crown remover

Computer-Guided Flapless Implant Surgery (bottom)

Abutment profile drill

Abutment profile drill is used to remove any piece of the bone that may interfere when the scan body is placed on the fixture or abutment.

Image 29: Abutment Profile drill

Bone interference is one of the major reasons why the abutment does not fully connect with the fixture .

Image 30: Incomplete connection of the fixture and abutment due to neighboring bone particles interfering

This issue arises when the fixture is inserted deeper into the alveolar surface than originally planned and thus, when the abutment (which is larger than the fixture) tries to connect on the top of the fixture, the bone surrounding this area can prevent clean connection. This is why the abutment profile drill is utilized; to remove any alveolar bone that interferes on the surface.

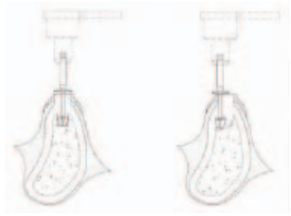


Image 31: Removing alveolar bone along the surface with abutment profile drill

The stop feature adjusts the height

Image 32: Adjusting the height using the stop scale on the drill

so that the drill can cut the bone on the surface without damaging the implant or other parts of the bone. The drill has a blade that is shaped like to the abutment profile so that the drill can remove the bone parts and leave an area similar to the abutment being placed.

Image 33: Illustrating bone removed by abutment profile drill, in a shape that is similar to the abutment's actual profile

Surgical Procedure

1. Equip the Surgical Guide

Position the surgical guide on the mouth and make sure it is stable.

Image 34: Placing the surgical guide in the mouth

It is important that the guide is positioned correctly. If the position of the surgical guide is off even slightly, the entire implant procedure can come astray. Even during the procedure, the position of the surgical guide must be checked regularly to make sure the surgical guide remains correctly positioned to prevent any errors.

2. Soft Tissue Punch

Following the surgical guide, insert the soft tissue punch drill and start drilling until the drill touches the bone. Remove a 3mm-cylindrical shape from the gum along the alveolar crest.

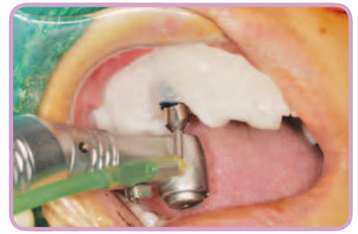


Image 35: Using the Soft Tissue Punch drill

It is okay to leave alone any soft tissue particles remaining, as consequent drills will remove them.

Image 36: Image showing some soft tissue particles remaining even after using the drill. These particles will be removed with subsequent drilling

3. Drilling alveolar crest

If the CBCT scan shows any signs of pointed or slated or irregular shape along the alveolar bone surface, bone flattening drill can be used to flatten the surface. The necessary depth of drill is determined using CBCT as a guide. Then the bone flattening drill is used to drill up to that depth.

Image 37: Bone flattening drill

The scale along the body of the drill should be used to identify the depth.

Image 38: Using the scale on the body of the drill to identify the depth of the drill in use

Another advantage of this drill is that it helps to remove any remaining soft tissue particles from the area.

Image 39: Image showing the alveolar region free of soft tissue particles

4. Guide drill

Insert the drill tube into the surgical guide's guiding sleeve, and then insert the Guide drill into the drill tube. Begin creating the first hole on the bone's surface (Image 40). If the CBCT image shows a flat alveolar crest surface, then it is possible to skip the Guide drill and move straight to the Ø 2.0 mm drill.

5. Ø 2.0 mm initial drill

The first drill used is the Ø 2.0 mm drill. The drill tube is inserted into the surgical guide's guiding sleeve. The Ø 2.0 mm drill is inserted into the opening on the drill tube.

Image 40: Guide drill in use

Image 41: Inserting the drill tube into the surgical guide's guiding sleeve

If Guide drill was used previously, then this drill can follow the hole created by the Guide drill to the point where the drill's stop scale meets the top of the surgical guide. The reason for using a drill tube when using a Ø 2.0 mm drill is because by doing so, the drilling can be guided from the early stages.

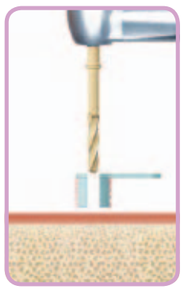


Image 43: Illustrating Ø 2.0 mm Drill being guided from the beginning stages

If the drill tube is not used, then the drill can only be guided in the later stages by following the initial cylindrical shape left by the earlier drills.

Image 44: Subsequent drills being guided by the path left from previous drills, without using a drill tube

Therefore, it is a good idea to use the drill tube from the early stages to increase the precision level. Subsequent drills that follow the Ø 2.0 mm drill, does not need to be used in conjunction with the drill tube since the larger-sized drills can simply follow the initial opening and increase the hole as it continues to drill. One thing to keep in mind when using a drill tube is since the drill's blade touches the drill tube's skin, the practitioner must be careful not to destroy the tube while drilling. For this reason, the practitioner must get a feel of the surgical guide's direction with the drill and drill in that direction. In addition, if it is difficult to position the drill within the drill tube because of the patient's smaller oral opening, a shorter (5mm) Ø 2.0 mm drill can be used or the drill can be inserted into the drill tube before sliding the drill tube into the surgical guide's guiding sleeve. If the shorter drill is used, do not try to drill until initial depth is achieved. Subsequent drills that do not require use of drill tube can establish that depth as needed.

6. Subsequent drilling

The drilling sizes that were determined during the simulation stage can be used in the order of increasing size. These subsequent drills can also be drilled without the assistance of a drill tube, but rather, follow the path from the earlier drills. Subsequent drills are directed by the cylindrical opening left by previous drills, and they are drilled until the stop level is achieved.

A

B

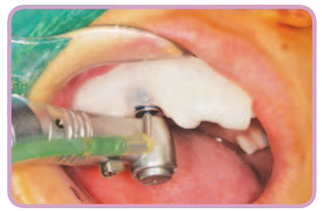


Image 45: A: Positioning the drill on top of the opening, B: Drilling into the path until the stop scale

Before and after drilling, and during drill switching, socket must be cleansed as much as possible.

Image 46: Cleaning the socket

This act of cleansing the socekt during drill switches is important as the heat from the drills can cause osteonecrosis, especially since there are limited opportunities for it to occur during procedures involving surgical guides. If a number of implants are being planted, the implants must be inserted after all the drilling has been completed. This is because during inserting implants, surgical guide's position can change due to implant connector's pressure.

7. Additional Drilling

For lower jaw area with bone marrow density of D1 or D2, and especially for compact bone areas, profile drill is used additionally to create a socket size similar to the size of the fixture.

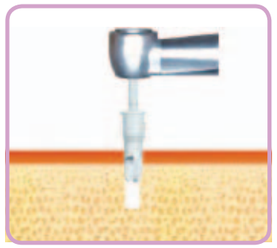


Image 47: Profile drill in use

This step is necessary to insert the fixture up to the determined depth without applying excessive torque.

8. Establishing abutment profile

If the fixture was inserted beyond alveolar surface, abutment profile drill is inserted into the surgical guide until it hits the stop level to create a shape similar to the abutment profile.

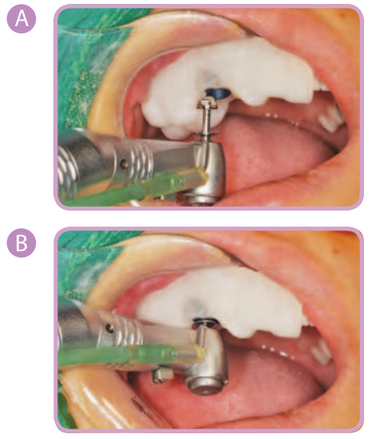


Image 48: A: Image of abutment profile drill, B: Abutment profile drill in use

This step also helps remove any alveolar bone pieces that may interfere once the abutment or scan body is connected.

9. Placing the implant

Before placing the implant, firstly clean the socket and make sure the area is completely free of any soft tissue. Pick up the implant using implant connector and insert the fixture into the bone along the surgical guide.

Image 49: Using the implant connector to pick up the implant and guide it into the fixture

During this stage, make sure the implant connector and fixture is connected completely and accurately. Implant can be inserted as it is being spun using a torque wrench or contra-angle handpiece. If there is enough opening, use the contra-angle handpiece first to insert the fixture and then use the torque wrench to adjust the vertical depth and hexagon's position based on the simulation.

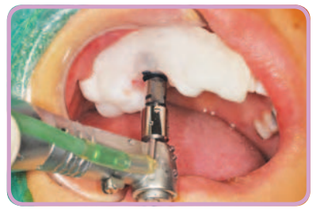


Image 50: Using the contra-angle handpiece to place the fixture

Image 51: Using the torque wrench to place the fixture

Thus, match the implant placement depth between surgical guide and the scale on the implant connector, then using the markers on the surgical guide and the implant connector, match the fixture's hexagon position with the implant's hexagon position.

Image 52: Matching the markers on the surgical guide and implant connector

The reason for using contra-angle handpiece before the torque wrench to insert the fixture is that rather than relying on the hand when using torque wrench, the motor of the contra-angle handpiece can help insert a certain way without shaking. Remove the connector once the implant has been placed. If excessive torque is applied on the fixture during placing the implant, internal hexagon can be damaged, which makes it difficult to remove implant connector from the fixture. It can also alter the position of placement, which can lead to the connector getting stuck on the wrong angle along the surgical guide. If this occurs, use the crown remover to connect with the implant connector to help remove it from the fixture.

10. Immediate prosthetic restoration or fitting healing abutment

If the implant secured its initial fixed position, immediate prosthetic restoration can take place by fixing the customized temporary PMMA abutment and crown (which were designed and manufactured pre-surgery) on the fixture.

Image 53: After placing the customized temporary PMMA abutment

Image 54: After placing the customized temporary PMMA crown

If there is a need to adjust the abutment and the tooth, it can be done inside the mouth. If immediate loading is not desired, occlusal (bite) adjustment can take place to prevent contact with antagonist tooth .

Image 55: After occlusal procedure to prevent contact with antagonist tooth

If the initial fixed position has not been established, mount the healing abutment instead. Make sure that healing abutment has an additional height of about 1.0 mm above the membrane region. This is because the mucous membrane can swell u to 0.7mm post-surgery. If the swelling covers up the healing abutment, switch the abutment with the one with more height. Diameter of the healing abutment should be about 1mm larger than the diameter of the soft tissue punch to allow surrounding mucous membrane a closer contact with the healing abutment.

Image 56: After placing the healing abutment

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